

Note on the Determination of the Planes of the Orbits of Jupiter's Satellites. By A. Marth.

The values of the nodes and inclinations of the orbits of *Jupiter's* satellites which are derived from observed eclipses are liable to a very sensible amount of uncertainty. The eclipses of longest duration give, indeed, the places of the nodes on *Jupiter's* orbit, while those of shortest duration furnish the inclinations. But as the eclipses which occur near the nodes vary little in duration, the ordinary errors of the observations, and, still more, the usual want of observations of successive eclipses at the proper epochs, leave considerable uncertainty in fixing the places of the nodes; and, in the case of the eclipses of shortest duration, if they occur far from the centre, an additional difficulty arises from the uncertainty of the real extent of the sections of the shadow by which the eclipses are produced.

So long as the observations of eclipses were the only trustworthy means available for finding not only the longitudes of the satellites in their orbits, but also the positions of their orbits, the ensuing uncertainty had to be submitted to as unavoidable. But since superior instruments and micrometers have become available, advantage ought to have been taken and ought to be taken to employ them at the proper times for the purpose of procuring those elements which cannot be derived from eclipse observations with the same degree of accuracy. As the apparent motion of the satellites at the beginning and end of nearly central eclipses amounts, during one minute of time, for

Sat. I., II., III., IV..

to $0'36, 0'29, 0'23, 0'17,$

when *Jupiter* is nearest to the Earth, or when *Jupiter* is at its mean distance to

$0''27, 0''22, 0''17, 0''13,$

it is easily seen that for determining the longitudes of the satellites in their orbits, micrometrical measurements are not likely to supersede in accuracy trustworthy observations of the times of eclipses, at least when the satellites do not pass too far from the centre of the shadow cone. But the case is different with regard to the determination of the planes of the orbits, especially the fixing of the nodes.

The most promising means for determining the longitudes of the nodes with accuracy will be found in micrometrical measurements of the distances at which the shadows of the satellites near their mid-transits appear from the centre line which bisects *Jupiter's* disc perpendicular to the axis of rotation, if these measurements are made about the times when the planes of the orbits pass through the Sun. That is the case in the present

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year, and though the opportunity may not be a very favourable one, since the nodal passages occur when *Jupiter* is too near the Sun to allow proper observations to be made, observers will not soon be so favoured as they were in 1849 or at the end of 1860, when, however, the opportunities were neglected, and they ought to make the best of present circumstances.

The inclinations γ and the ascending nodes Γ of the orbits of the four satellites in reference to the plane of *Jupiter's* equator have been given since 1876, at sufficiently close intervals, in my annual Ephemerides for physical observations of *Jupiter*, the nodes being reckoned from O, the point of the descending node of the planet's equator on its orbit. They depend on data derived from Damoiseau's tables of the satellites, and therefore contain the imperfections of the tables affecting the latitudes of the satellites. The following is a continuation of these values for the present and for the next apparition of the planet:—

	Sat. I.		Sat. II.		Sat. III.		Sat. IV.	
	γ_1	Γ_1	γ_2	Γ_2	γ_3	Γ_3	γ_4	Γ_4
1883.								
July 28	0°0108	330°8	0°4814	332°38	0°1634	256°93	0°3180	330°80
Sept. 26	°0108	328°5	°4820	330°43	°1627	256°47	°3175	330°70
Nov. 25	°0108	326°3	°4826	328°49	°1620	256°03	°3171	330°60
1884.								
Jan. 24	°0108	324°1	°4832	326°54	°1613	255°61	°3168	330°50
Mar. 24	°0108	322°0	°4838	324°60	°1607	255°21	°3166	330°39
May 23	°0109	319°8	°4844	322°66	°1601	254°83	°3166	330°29
July 22	°0110	317°7	°4850	320°72	°1595	254°48	°3166	330°20
Sept. 20	°0111	315°7	°4857	318°79	°1589	254°15	°3167	330°11
Nov. 19	°0111	313°7	°4863	316°86	°1582	253°84	°3169	330°04
1885.								
Jan. 18	°0112	311°9	°4870	314°94	°1575	253°55	°3172	329°98
Mar. 19	°0113	310°1	°4876	313°02	°1568	253°28	°3176	329°93
May 18	°0114	308°4	°4883	311°11	°1561	253°02	°3179	329°91
July 17	0°0115	306°7	0°4889	309°20	0°1553	252°77	0°3183	329°90

The angular distances from the centre of the disc at which, heliocentrically, the apparent orbits of the satellites cross the central meridian will be, according to the assumed data, the following:—

	Sat. I.	Sat. II.	Sat.	Sat. IV.
1884, Mar. 24	—1°09	—2°34	—3°52	—5°70
May 23	—0°60	—1°71	—2°26	—3°72
July 22	—0°11	—1°07	—0°99	—1°74
Sept. 20	+0°37	—0°43	+0°25	+0°22
Nov. 19	+0°84	+0°21	+1°48	+2°16
1885, Jan. 18	+1°30	+0°85	+2°69	+4°05
Mar. 19	+1°74	+1°49	+3°86	+5°90

The conjunction of *Jupiter* with the Sun takes place on August 7. The eclipses of longest duration of the satellites III. and IV. occur on September 4, when *Jupiter* is only 20° distant from the Sun. For testing and correcting the tabular places of the nodes, corresponding observations of the shadows when south and when north of the centre of the disc are required, and observers with superior telescopes and micrometers at their command should endeavour to procure such observations during the latter part of the present and the first half of the next apparition of *Jupiter*.

As regards the determination of the inclinations, it is at present uncertain whether the inclination of the orbit of the *second* satellite can be derived from micrometrical measurements with greater advantage than from eclipses, as the degree of accuracy with which the distances of the shadow can be measured is not yet known. In the case of the *third* satellite, where the number of observed eclipses of shortest duration is much more limited, micrometrical measurements, made at the proper times, will be of essential service for settling the inclination. And in the case of the *fourth* satellite they will be found indispensable if the existing uncertainty is to be effectually removed.

To appreciate this necessity properly, and to get some fair notion of what evidence the observed eclipses of the fourth satellite really furnish for correcting the tabular values of the node and inclination, it may be sufficient, in the absence of an accessible general collection of eclipse observations, to consider the result of those made at Greenwich. The Greenwich eclipse observations, which extend over a longer period than those at any other observatory, have been made with great assiduity, and, I presume, no fair opportunity has been missed; yet, in the course of forty-eight years—from 1836, the year of the publication of Damoiseau's tables, to 1883—the number of eclipses, of which both the beginning and the end have been observed, is only *five*, and of one-sided observations, nine disappearances and sixteen reappearances of the satellite have been secured. None of the five complete observations affords help for correcting the latitude of the satellite. Observations made near the beginning and ending of a cycle of eclipses, when a slight error in latitude shows itself in a telling manner in the observed duration, are very rare. The interesting observation made 1877, August 29, by Todd at Adelaide (*Monthly Notices*, vol. xxxix. p. 16), when the satellite never disappeared, but was reduced to a mere speck of light skirting the margin of the shadow, indicated such an error very strikingly, for the eclipse was, according to the tables, not the first, but the second one of a new cycle, and the tabular duration was seventy-nine minutes. The eclipse of April 4, 1883, the second one of the present cycle of eclipses, showed a similar error, for, according to the observation made with the telescope of the Oxford heliometer by Bellamy (*Monthly Notices*, vol. xliii. p. 446) the satellite disappeared for only six instead of the

predicted eighty-six minutes, while if the "last seen" and "first seen" really refer to corresponding phases, the predicted time of conjunction is nearly correct.

But important as these two observations will ultimately be for determining the extent of the shadow section, they must be supplemented by corresponding observations of eclipses occurring towards the ends of cycles, in order to allow further inferences to be drawn. The only observation near the end of the last cycle which I have yet seen is a one-sided one, a disappearance observed 1880, May 30, by Tebbutt at Windsor, New South Wales (*Astron. Nachr.*, No. 2,541), from which it may be inferred that the tabular longitude of the node requires a sensible positive correction, as the measurements of Bessel and of Schur had already rendered probable. Observers ought to be on the alert early in 1886 to get complete observations of some of the last eclipses in the present cycle.

Observations of Sun-spot Spectra in 1883. By the Rev.
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The daily routine work at Stonyhurst Observatory has now for some years included a careful drawing of the solar surface on every available occasion, and also a complete measure of the Sun's chromosphere. Since 1882 a spectroscopic examination of Sun-spots has been added to the previous solar work, but attention has been directed exclusively to the red end of the spectrum, from D to B, as the more refrangible portion is being already carefully studied by others. The following paper is a synopsis of the observations made during the past twelve months, and will, it is hoped, present the results in the most simple form for comparison with the work of other observers. In numbering the lines seen widened or darkened in the spots, the figures published in the British Association Report for 1878 have been followed throughout, and the numbers of both Kirchhoff and Ångström are given for the convenience of reference. The instrument used in these observations is an automatic spectroscope of Browning, in which a dispersion of 2, 4, 6, 8, 10, or 12 prisms of 60° can be readily obtained, and a Christie half-prism has been adapted to the original spectroscope, by which the dispersion previously obtained can be trebled. The figures in the columns headed "widened" and "darkened" will not give averages, as clouds often stop an observer in the middle of his scrutiny, and then only a small proportion of the affected lines may have been noted.